

A Polar Volatiles Laboratory

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Shackleton Crater
ESA Smart-1

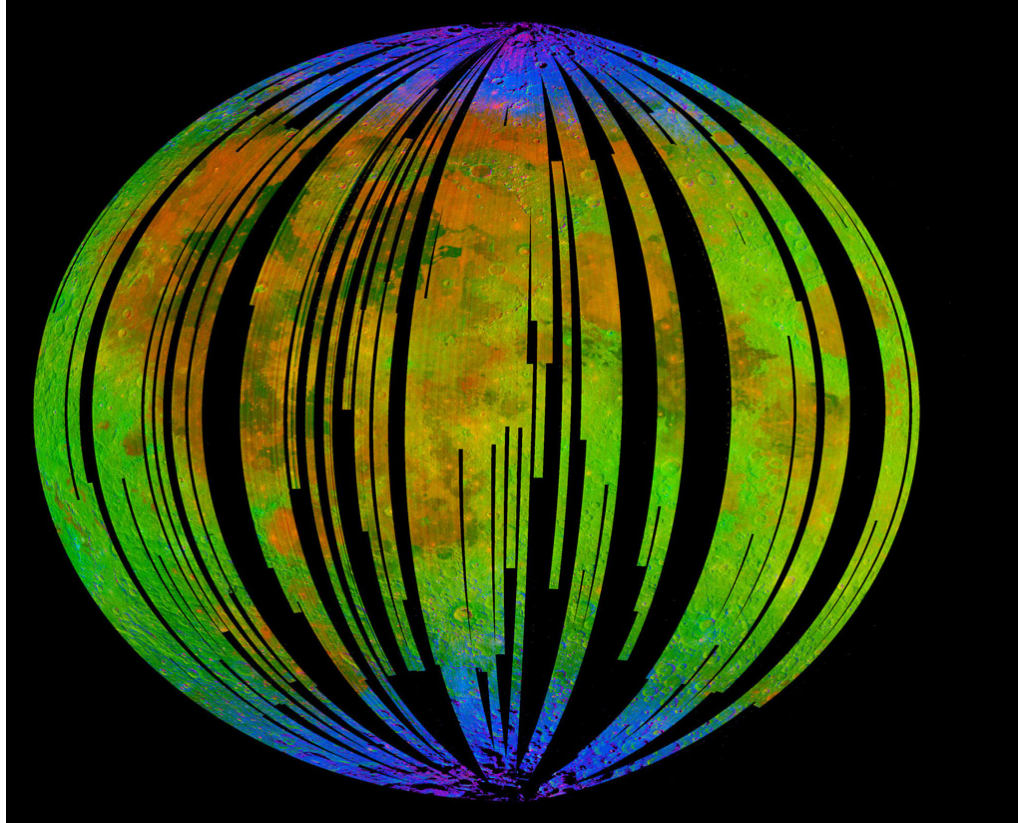
Evidence of Lunar Polar Volatiles

- 1998: Lunar Prospector neutron spectrometer finds enhanced hydrogen at lunar poles
- 2009: LCROSS impact found $5.6 \pm 2.9\%$ ice in regolith at Cabeus crater
- 2009: Chandrayaan-1 M3 finds widespread evidence of OH

Ice at the Poles

- It is probably that ice in permanently shaded craters originates from comet impacts.
 - Impact vaporisation
 - Migration to the poles
 - Condensation
 - Environmental effects over byrs
- Nevertheless, it is expected that information remains concerning the composition of their original sources
 - the role of comets in seeding terrestrial planets
 - the nature of volatiles and pre-biotic organic materials

Water (or at least OH) on the Moon



False colour rendition of the global mineralogical observations of the Moon conducted by the M³ instrument on Chandrayaan-1 (Pieters et al., 2009). Here blue indicates the presence of absorption bands at wavelengths close to 3 μm attributed to OH and/or H₂O (Image: M³/NASA/ISRO).

OH and H₂O

- The evidence of creation, retention, migration and destruction of OH and H₂O has profound implications to airless bodies and the availability of water (ice) in the inner solar system
- This is a phenomena that we must understand

Astrobiology

- Lunar polar ices will be subject to galactic cosmic ray irradiation and so will undergo 'Urey-Miller-like' organic synthesis reactions.
- Therefore lunar polar deposits provide a 'local' laboratory for the study of such process that may have great significant for the possible creation of organic materials in the icy mantles of interstellar grains

Future exploration of the Moon

- The availability of water on the Moon enhances the feasibility of manned exploration
 - Oxygen
 - Rocket fuel
 - Drinking water
 - ...

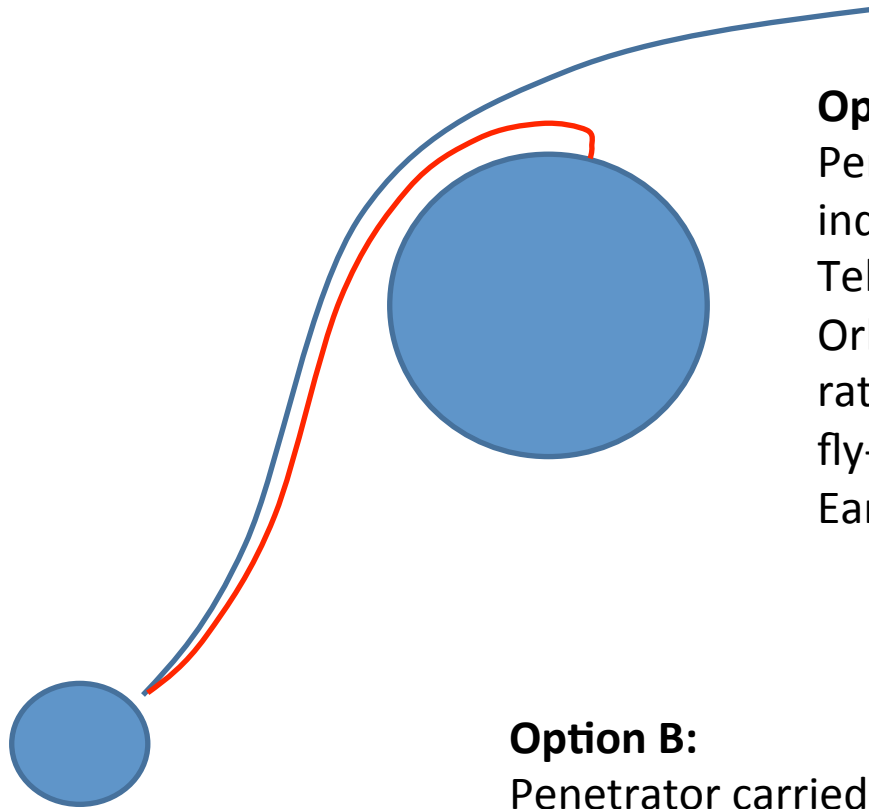
The Challenge

- To make an *In Situ* confirmation of the presence of volatiles in a permanently shaded, polar, lunar crater.
- To study their nature
- At lowest cost

Mission Concept

- Permanently Shaded Crater impact site
- Short-duration mission
- In situ operations
- Penetrator-based with telecoms relay element
- Volatiles acquisition and analysis package

Orbital Options



Option A:

Penetrator and telecom relay independently arrive at Moon
Telecom relay need not enter Lunar Orbit since data volume and telemetry rates would permit reception during fly-by and later re-transmission to Earth

Option B:

Penetrator carried by telecom relay satellite into polar lunar orbit.
Penetrator descends from lunar orbit (40km).

Option A

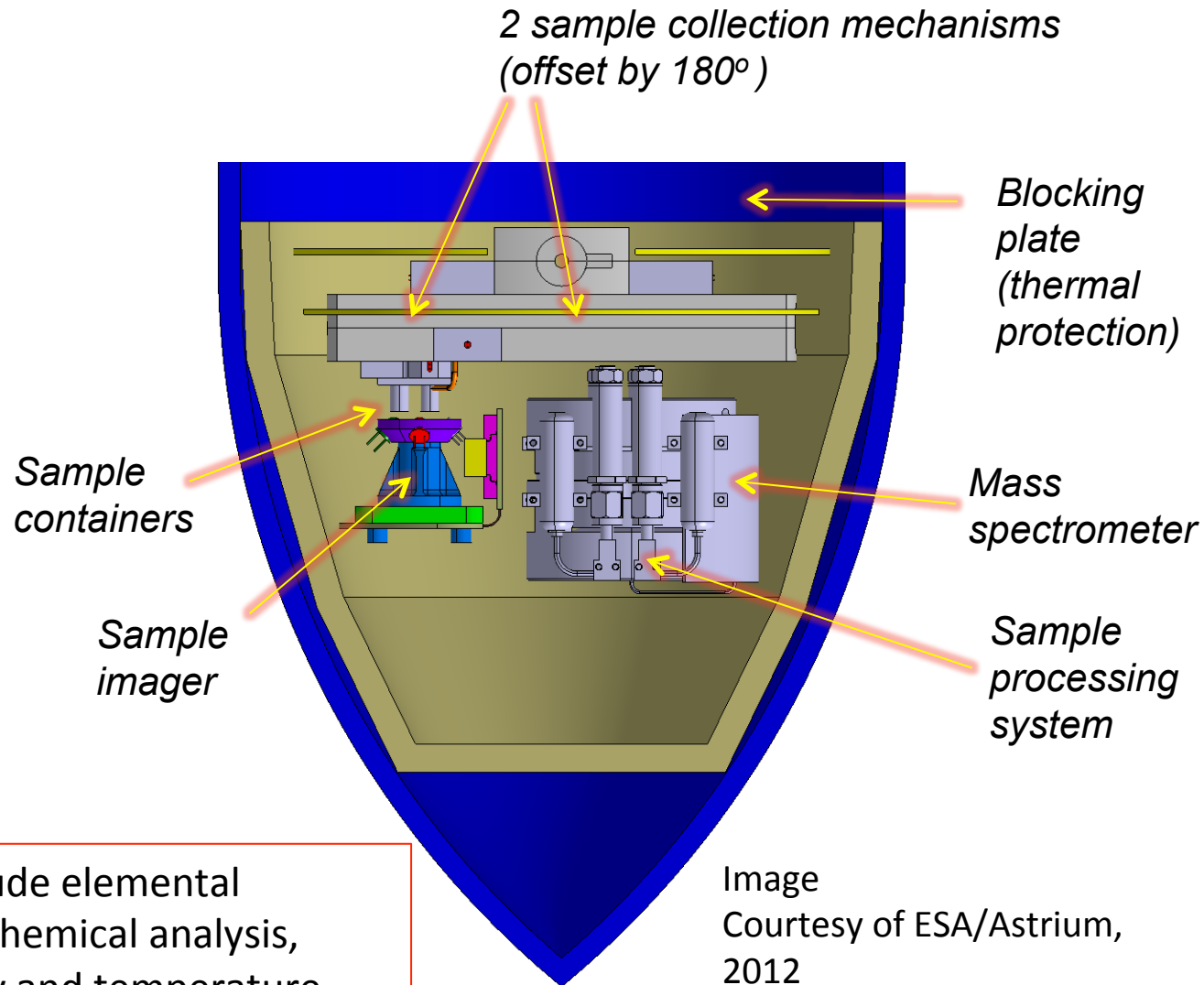
- Dual launch of penetrator element and telecom relay element
- Penetrator implanted in shaded polar crater 2-3 hours prior to fly-over of relay spacecraft
- Penetrator element transmits data in a repeating loop.
- Relay satellite's sole task is to relay penetrator data, no need for lunar orbit since data can be recorded and transmitted after lunar flyby

A simple mission

- Short duration
 - Fully battery powered with need for only ~1kg batteries
 - Thermal insulation limits the need for internal heating even in shaded crater, RHU's are avoided
 - Short mission operations (few days)
- Penetrator fully automated
 - No need for 'accurate' on-board clock
 - No need for receiver on-board Penetrator

Payload Design

- <4 kg (including sampling system & margins)
- Located in penetrator nose
- Utilises common electronics
- Thermally isolated from rear of penetrator



Measurements will include elemental composition as well as chemical analysis, visible structure, density and temperature

Penetrator Element

- Based on Lunar A
- Penetrator Mass $\sim 10\text{kg}$
- Two stage descent
 - Stage 1 – lunar capture
 - Stage 2 – ‘zero’ relative velocity at 40km altitude

Mission Cost

Penetrator	€11m
Penetrator Delivery System	€30m
Flyby spacecraft	€15m
Launcher (Vega)	€35m
Operations	€5m
Total cost <	€100m